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RUBBER ACREAGE SUPPLY RESPONSE IN THAILAND: A COINTEGRATION APPROACH

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ABSTRACT

This paper estimates the acreage supply response of natural rubber in Thailand using cointegration methods. Results show that a unique long-run relationship exists between area planted, the rubber price and the replanting subsidy, and the rubber price is weakly exogenous. The short-run own price elasticity of acreage response is low at 0.04 whereas the corresponding long-run elasticity is 2.24, and the use of pricing policy takes a long lead time to take effect. The acreage elasticity in response to a change in the subsidy is 1.17 and the replanting subsidy is a key driver for increasing rubber production.

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INTRODUCTION

Thailand is the world's largest producer of natural rubber: in 2009, it produced 3.09m tonnes or 30% of world output (FAO). Exports comprise almost 90% of production (2.74m tonnes) and Thailand is the largest exporter with 42% of world exports.[1] While the structure of exports in the Thai economy over the last 40 years has changed from a heavy reliance on agricultural commodities towards manufactured products (FAO), exports of the former are still important and amount to 18% of total exports (CAIOAE, 2010a). Rubber is the second largest agricultural export after rice comprising 16% of total agricultural exports. The rubber area is 2.6m hectares or 13% of Thailand's agricultural area while the harvested area is 1.8m hectares (CAIOAE, 2010b). The rubber sector is also an important source of employment where more than one million farm households work directly and more are employed in related industries such as tyres and rubber gloves. The importance of the rubber sector in Thailand's economy is clear.

The two traditional rubber areas in Thailand are in the peninsular part of the South and the coastal area of the East. In the late-1950s, major production problems were low-yielding varieties, poor harvesting and maintenance practices, and poor quality of products. To address these problems, the Thai government enacted the Rubber Replanting Aid Fund Act (1960), and the Office of Rubber Replanting Aid Fund was set-up to administer a replanting subsidy which came into force in 1962. Until 1989, the entire subsidy was used for replanting old rubber areas by established farmers. Thereafter, the government encouraged planting in new areas, and by 2006 more than half the subsidy was spent on planting on new lands (ORRAF).[2] The replanting subsidy is paid in seven instalments over the six-year gestation period between planting and harvesting. The largest instalment (of about 24,000 baht/ha. in 2008) is paid in the first year for land clearance, fencing, seedlings, planting and fertiliser application. Five subsequent annual instalments (of 8,000-11,000 baht/ha.) subsidise weeding and fertiliser application. The average subsidy in 2008 was 69,000 baht/ha. (ORRAF).

The replanting subsidy is a major plank of Thailand's rubber policy and is funded mainly from a cess (or export) tax. Its aim is to increase production via technological change whereby farmers are provided with access to high-yielding varieties, fertilisers and extension. New rubber areas have been established in the Northern and North-Eastern regions, and farmers in traditional areas have been encouraged to replant old rubber holdings with high-yielding varieties. The scale of production remains small: there are over one million farms of less than eight hectares which comprise of over 90% of the rubber area, and the average farm is less than 2ha.[3]

The government has also implemented other domestic rubber policies. First, it undertakes research into high-yielding varieties, good-practice harvesting systems and tree maintenance to improve methods of cultivation. Second, it implements marketing schemes which have included the establishment of central and local markets, and support for co-operatives. Third, it occasionally intervenes directly in the domestic market: for example, in 1999-2006 the One Million Rais Project was launched which aimed to establish 160,000 hectares of new plantation. The Thai government also plays an important role via international organisations to stabilise world prices.

Agricultural supply response is critical to resource allocation. How the supplies of agricultural commodities respond to economic incentives is measured by supply elasticities, and policy-makers need to understand their characteristics and magnitudes to assess policy efficacy (Hennebery and Tweeten, 1991). This paper examines the supply response of natural rubber in Thailand. We seek to identify the factors that determine rubber supply and to measure their magnitudes, and of particular interest is the effect of the subsidy. The paper is organised as follows: Section 2 provides a selected literature review; Section 3 presents our empirical method; Section 4 discusses the data and empirical results; and Section 5 concludes.

A SELECTED LITERATURE REVIEW

French and Matthews (1971) and Akiyama and Trivedi (1987) observe that the supply of perennial crops has two distinctive characteristics. First, there is a biologically-determined gestation period between planting and harvesting which is followed by a productive period during which there is a gradual decline of productive capacity. Rubber trees have an unproductive, immature phase of around seven years between planting and the start of harvesting, and a productive, mature phase of around 20-25 years. Second, there are significant adjustment costs of planting and removal which are restricted by past decisions, technology, and the availability of land, labor, and credit. The implications of these characteristics are threefold. First, perennial crop production is dynamic: production depends on a biologically-determined life-cycle and in particular on the total tree stock, different maturities, and the availability of new improved varieties. Second, current production depends on previous input levels. Third, farmers must invest using long-term planning strategies. We now review some studies of perennial crop supply response.

Bateman (1965) examines cocoa in Ghana and is one of the first to adopt Nerlove's (1958) framework to study perennials. Since planting decisions are based on expectations of income streams spread over the life of the tree and maintenance costs, farmers maximise the present value of expected profits with respect to area planted. Area therefore is a function of the present value of expected prices, expected marginal and total yields, and expected marginal costs. Assuming that the producer price is the most important factor affecting income expectations, Bateman postulates that area is a function of discounted expected own and substitute prices. Ady (1968) and Behrman (1968) use similar Nerlovian models for cocoa but instead of examining actual acreage, desired acreage is modeled as a function of expected own and substitute prices.

A seminal study of perennial supply response is French and Mathews (1971) who formulate a theory to explain new plantings and acreage adjustment. Separate equations are specified *inter alia* for desired output and tapped acreage, acreage removals and average yield, and Nerlovian partial adjustment is adopted for new plantings where acreage gradually adjusts to its desired level. The model is applied to the US asparagus industry and a single, reduced-form equation is obtained which specifies acreage as a function *inter alia* of lagged own price and lagged acreage but the structural parameters are under-identified. Extensions of this model include Rae and Carman (1975), Alston *et al*. (1980), French *et al*. (1985), Bushnell and King (1986), Kinney *et al*. (1987), French and King (1988), French and Willett (1989), French and Nuckton (1991), Carman and Craft (1998) and Devadoss and Luckstead (2010).

Wickens and Greenfield (1973) argue that the application of the Nerlovian supply response model causes difficulties in quantifying investment and harvesting decisions. Instead, they propose a structural model for Brazilian coffee consisting of a vintage production function along with investment and harvesting functions, and output is determined by investment dynamics and the production cycle. In the output response equation, prices are modeled by Almon polynomial lags where the lag shape is similar to the yield pattern after three years. The model has four limitations. First, the structural parameters are under-identified. Second, the inclusion of a non-price variable in the planting equation is problematic since it becomes a distributed lag term in the output equation. Third, the yield pattern of perennial crops may not be correctly estimated by Almon lags as weights of lagged prices could diverge from the yield pattern. Fourth, the sum of the coefficients of lagged output is rarely close to unity which is inconsistent with theory (Akiyama and Trivedi, 1987). Nevertheless, the model has been widely applied with little or no modification and examples include Dowling (1979) and Tan (1984) for rubber in Thailand, and Hartley *et al*. (1987) for rubber in Sri Lanka. Other models of perennial supply response include Akiyama and Trivedi (1987), Dorfman and Heien (1989) and Alston *et al.* (1995).

Many of the early empirical studies of supply response use ordinary least squares (OLS) regression models and Nerlove's (1958) *ad hoc* partial adjustment and/or adaptive expectations framework to estimate supply response. Nerlovian models imply restrictive geometrically declining lag structures, and those that use *ad hoc* lag structures may also capture dynamics inadequately. Further, most economic time series are trended over time and OLS regressions between trended series may produce significant but spurious results (Granger and Newbold, 1974). This spurious regression problem is common to many of these studies, and more recent ones have used cointegration methods. For example, Engle and Granger's (1987) single-equation cointegration method is used by Abdulai and Rieder (1995) to analyse cocoa production in Ghana, and by Alias *et al.* (2001) to examine the supply of palm oil, rubber and cocoa in Malaysia. Similarly, Johansen's (1988) cointegration procedure is used by Mesike *et al*. (2010) to examine rubber supply response in Nigeria, and by

Alias and Tang (2010) to examine the supply of palm oil in Malaysia. The conclusion to these studies is that cointegration methods are preferred since they provide more general dynamic structures than Nerlovian models.

Most studies of rubber supply response in Thailand estimate output response while some estimate acreage response, and most use OLS although other methods include maximum likelihood (ML) and two and three stage least squares (2SLS/3SLS). Behrman (1971), Stifel (1973), DAER (1989), Changkid (1990), and Burger and Smit (2003) use an atemporal framework and simple OLS. Nerlovian models are adopted by Grilli (1979), Man and Blandford (1980), Jampasut (1981), Hataiseree (1983), Suwanakul and Wailes (1987), Yibngamcharoensuk (1988) and Arthannarong (1994). *Ad hoc* lag structures to capture expectations and supply lags are used by Sakarindr (1979), Meyanathan (1983), Aroonsiriporn (1989) and Pipitkul (2004) while Dowling (1973) and Tan (1984) adopt Almon lag structures. Short-run own price output elasticities typically vary between zero and 0.8 and average around 0.3; medium-run elasticities vary between 0.64 and 3.95; and long-run elasticities typically vary between 0.25 and 2.64 although Tan (1984) provides an unlikely estimate of 6.71. A summary of studies that examine rubber supply response in Thailand is shown in Table 1.

The criticisms of restrictive lag structures and spurious regression are common to many of these studies. Moreover, some omit relevant variables which may cause bias. For example, competitive crop prices are rarely incorporated although exceptions are Stifel (1973), Jumpasut (1981), Hataiseree (1983), and Yibngamcharoensuk (1988). Natural rubber supply response is also influenced by non-price variables such as government policy and technological change but it is difficult to incorporate these variables directly and most studies proxy their impacts by a time trend. These criticisms cast doubt on the validity of previous results.

To address the problems of restrictive lag structures and spurious regression, we use Johansen's (1988) cointegration procedure. To address the problem of omitted variables, we follow the theoretical literature on perennial agricultural supply response and hypothesise that rubber supply is determined by its own price, alternative crop prices, and input prices. The alternative crop prices considered here are those of paddy and palm oil while input prices are the fertiliser price and the wage rate. We also include government subsidies to capture the effects of the replanting program.

EMPIRICAL METHOD

OLS regressions between time series that are non-stationary are generally spurious and such series must be first-differenced to render them stationary. Where variables which are integrated of order one, I(1), move together and their linear combination is stationary, the series are cointegrated and OLS regressions are meaningful. Cointegration implies the existence of a long-run equilibrium relationship which can only exist when at least two variables are integrated of the same order (Granger, 1981). Johansen's (1988) procedure is used to test for cointegration in the vector autoregressive (VAR) model. It is based on maximum likelihood estimation of the associated vector error-correction model (VECM):

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \cdots + \Gamma_{k-1} \Delta z_{t-k+1} + \Pi z_{t-1} + u_t \qquad (1)$$

TABLE 1. STUDIES OF SUPPLY RESPONSE OF NATURAL RUBBER IN THAILAND

Author	Period of study	Method (equation)	Dep. variable	Short run elasticity	Medium run elasticity	Long run elasticity
Behrman (1971)	1947-65	OLS, ML (single)	Output	0.41, 0.04	-	0.19
Stifel (1973)	1913-62	OLS (single)	New planting	0.80	-	-
	1926-68		Output	0.15-0.77	-	-
Dowling (1979)	1915-75	OLS (single)	Output	0.09-0.18	0.64-1.92	1.21-2.64
Grilli (1979)	1955-75	OLS (single)	Output	0.25	-	-
Sakarindr (1979)	1955-72	2SLS (simultaneous)	Tappable area	0.11	-	-
			Output	0.12		
Man and Blandford (1980)	1960-77	2SLS (simultaneous)	Output	0.64	-	1.45
Jumpasut (1981)	1947-79	OLS (single)	Output	0.59	-	0.25
Hataiseree (1983)	1964-80	2SLS (simultaneous)	Output	0.21	-	-
Meyanathan (1983)	1972-76	OLS (single)	Output	0.02	-	-
Tan (1984)	1956-78	OLS (single)	Output	0.40	3.95	6.71
			Area planted	-0.10		
Suwanakul and Wailes (1987)	1954-83	OLS (simultaneous)	Tappable area	0.03	-	0.31
			Output	0.21	-	0.56
Yibngamcharoensuk (1988)	1964-83	OLS (single)	Area planted	0.05	-	-
	1969-83		Output	0.11		
Aroonsiriporn (1989)	1966-86	3SLS (simultaneous)	Tappable area	0.002	-	-
DAER (1989)	1961-76	2SLS (simultaneous)	Output	0.24	-	-
Changkid (1990)	1979-87	OLS (single)	Output	0.41	-	-
Burger and Smit (1997)	1974-93	OLS (single)	Output	-	-	0.25
Pipitkul (2003)	1975-02	2SLS (simultaneous)	Output	0.08	-	-

where z_t is a (n×1) vector of endogenous I(1) variables, $\Delta z_t=z_t-z_{t-1}$, Γ_i and Π are (n×n) matrices of parameters with $\Gamma_i=-(I-A_1-A_2-\ldots-A_i)$ for i=1,…,k-1 where A_i is a (n×n) matrix of parameters, $\Pi=-(I-A_1-A_2-\ldots-A_k)$, and u_t~I(0) are white noise errors. Information about the number of long-run cointegrating relationships among the variables in z_t is given by the rank of Π, denoted by r. If Π is of reduced rank where $r\leq(n-1)$, there are r distinct cointegration vectors and Π can be decomposed into two (n×r) matrices α and β such that $\Pi=\alpha\beta'$ where $\beta' z_t$ is stationary. Here, α is the error-correction term and measures the speed of adjustment in Δz_t, and β contains r cointegrating vectors, that is, the long-run cointegrating relationships between the non-stationary variables in z_t. Johansen (1988) uses the reduced rank regression procedure to estimate α and β, and trace statistics are used to test the null hypothesis of at most r cointegrating vectors against the alternative that the number of cointegrating vectors is greater than r.[4] Short-run adjustments to changes in z_t are contained in Γ_i. The Schwarz Bayesian criterion is used to determine lag length, k.

Deterministic components consisting of a constant, a trend, t, and intervention dummies, D, can be added to (1). To illustrate, consider the simple case of a VAR(1) where the short-run dynamic effects Γ_i for i=1,…,k-1 are zero. The VECM in (1) becomes:

$$\Delta z_t = \alpha \begin{bmatrix} \beta \\ \mu_1 \\ \delta_1 \end{bmatrix} \tilde{z}_{t-1} + \mu_2 + \delta_2 t + \Psi D + u_t \tag{2}$$

where $\tilde{z}'_{t-1}=[z'_{t-1}, 1, t]$. There are three realistic models (denoted as Models 2-4) implicit in (2) which are nested by imposing restrictions (Harris and Sollis, 2005, pp.133-134).[5] In Model 2, the data have no linear trends in levels so there is a zero mean in the first difference form, the constant is restricted to the long run or to the cointegration space, and $\delta_1=\delta_2=\mu_2=0$. In Model 3, the data have linear trends in level form so the relationships among the I(1) variables can drift, there is only a constant in the short-run model, and $\delta_1=\delta_2=0$. Model 4 is where there is a linear trend in the cointegration vector(s), which accounts for technological change in our case, there is no trend in the short-run model, and $\delta_2=0$. To test between these models, the Pantula principle (Harris and Sollis, 2005, pp.134-135) is used to test the joint hypothesis of both rank and the deterministic components (Johansen, 1995).

We test three hypotheses. First, we test for unit roots where the null, that z_{it} is trend stationary, is $\beta_j=0$ for all i=1,…,n and $i\neq j$. Stationary variables do not enter the long-run cointegration space but only influence the short-run model. Second, the null that z_{it} is excluded and is not part of the equilibrium relationship is that $\beta_i=0$ for i=1,…,n. Third, weak exogeneity is where z_{it} does not respond to deviations from the long-run equilibrium and the null is that $\alpha_i=0$ for i=1,…,n (Harris and Sollis, 2005, pp.135-136).

A weakly exogenous variable remains in the cointegrating vector but its short-run behaviour cannot be modeled because it disappears from the left-hand side of the VECM in (2), entering on the right-hand side instead. To illustrate, consider the case of $z_t=[z_{1t}, z_{2t}, z_{3t}]'$ where there is one cointegrating vector (r=1), and z_{3t} is weakly exogenous. Conditioning on the weakly exogenous z_{3t} by imposing the restriction that $\alpha_3=0$, the VECM in (2) becomes a conditional VECM:

$$\Delta y_t = \alpha \begin{bmatrix} \beta \\ \mu_1 \\ \delta_1 \end{bmatrix} \tilde{z}_{t-1} + \Gamma_0 \Delta z_{3t} + \mu_2 + \delta_2 t + \Psi D + u_t \quad (3)$$

where y_t=[z_{1t}, z_{2t}]', α=[α_1, α_2]' and Γ_0 is a (2×1) vector of parameters. Estimating the conditional VECM usually improves the stochastic properties and stability of the rest of the system (Harris and Sollis, 2005, pp.137-138; Juselius, 2006, p.198).

Following Juselius (2006, pp.73-77), the trace correlation and diagnostic multivariate mis-specification tests of the residuals are presented. The trace correlation is an overall goodness of fit indicator and is approximately the average-R^2 in the n VAR equations. The Ljung-Box Lagrange multiplier (LM) test tests the null of no autocorrelation up to second order. The autoregressive conditional heteroscedasticity (ARCH) test tests the null of no conditional heteroscedasticity up to fourth order. The Doornik and Hansen (2008) test tests the null of non-normality.

DATA AND RESULTS

Rubber supply response models can be estimated for total production and its two components, tapped acreage and yield. Acreage is preferred in many studies of agricultural supply response because it measures intended supply and because yield is subject to more random variation than acreage due to uncontrollable factors such as the weather. We examine acreage response. The data consist of annual time series data at Thailand's national level for 1962-2009 (48 observations) and variables comprise planted acreage, the domestic rubber price and competing crop prices of paddy and oil palm, the fertiliser price, the wage rate as proxied by manufacturing wages, the aggregate replanting subsidy, and weather as measured by average annual rainfall. All nominal prices are deflated by the GDP deflator (2005=100) and natural logarithms are used throughout.

From preliminary estimation of (2), we find no cointegrating relationships in models that include competing crop prices, the fertiliser price, and the wage rate. Thus planted acreage, A_t, is assumed to be determined by own price, P_{rt}, and the replanting subsidy, S_t.[6] Outliers where residuals exceed two standard deviations are evident in 1965, 1966 and 1967 and three corresponding short-run impulse dummies (D65, D66 and D67) are included to improve statistical credentials following Hendry and Mizon (1993). The Schwarz Bayesian criterion chooses one lag. Table 2 shows trace statistics for this 'full model' and the Pantula principle indicates that Model 2 with one cointegrating vector is preferred.

TABLE 2. TRACE STATISTICS FOR THE FULL MODEL

H_0: r	H_1: (n-r)	Model 2	Model 3	Model 4
0	3	81.62 [0.00]	51.94 [0.00]	65.87 [0.00]
1	2	6.18 [0.94]*	2.73 [0.97]	9.27 [0.95]
2	1	0.93 [0.94]	0.33 [0.57]	2.14 [0.95]

Notes: 1. p-values in the square brackets.
*2. * indicates where the null is not rejected using the Pantula principle.*

Table 3 shows the cointegrating vector normalised on A_t and diagnostic mis-specification tests. The trace correlation is low, the Ljung-Box LM(2) test indicates mild second-order autocorrelation, ARCH(4) effects are absent, and the Hansen-Doornik test indicates that residuals are normally distributed. Results of hypothesis tests are shown in Table 4. First, the nulls of stationarity imply that all variables have a unit root. Second, the nulls of individual exclusion imply that all β_i-coefficients are significant. Third, the nulls of weak exogeneity for A_t and S_t are rejected but that for P_{rt} is not. Thus, own price is weakly exogenous and is not responsive to changes in acreage (or the replanting subsidy).

The model is re-formulated as a conditional VECM by conditioning on the weakly exogenous P_{rt}, as in (3). As in the full model, the conditional model is estimated with one lag. Normalising the cointegrating vector on A_t, diagnostic mis-specification tests are shown in Table 3. The trace correlation is substantially higher than in the full model, the Ljung-Box LM(2) test again indicates mild second-order autocorrelation, ARCH(4) effects are absent, and the residuals are normally distributed. We conclude that the residuals are reasonably well-behaved and the conditional model is a better representation of the data than the full model. We now re-test hypotheses on the conditional model and the results are shown in Table 4. Both A_t and S_t are non-stationary, both β_i-coefficients are significant, and both nulls of weak exogeneity are rejected.

Parameter estimates in the conditional model are shown in Table 3. As in the full model, all have *a priori* expected signs and are significant. Moreover, they are similar to those in the full model and estimated parameters are robust to either specification. The long-run elasticity of acreage response with respect to the replanting subsidy is 1.17, and the subsidy is an important determinant of acreage response. The short- and long-run price elasticities of acreage response are 0.04 and 2.24. In the short run, farmers can make only small changes to area in response to a price change, whereas in the long run they can make substantial changes.

TABLE 3. MODEL ESTIMATES

	Full Model	Conditional Model
Cointegrating vector (normalised on A_t)		
Constant	-18.960 (3.40)	-19.139 (3.36)
P_{rt}	2.249 (8.55)	2.244 (8.11)
S_t	1.142 (2.40)	1.168 (2.43)
Adjustment coefficients		
α_A	-0.030 (12.65)	-0.030 (13.83)
α_{P_r}	0.022 (1.00)	-
α_S	-0.046 (2.85)	-0.041 (2.63)
Short-run estimates in ΔA_t-equation		
ΔP_{rt}	-	0.038 (2.65)
D65	-0.088 (5.23)	-0.088 (5.23)
D66	-0.048 (2.87)	-0.048 (2.87)
D67	0.102 (5.90)	0.102 (5.90)
Mis-specification tests		
Trace correlation	0.46	0.70
LM(2) test	15.59 [0.08]	10.12 [0.04]
ARCH(4)	151.39 [0.32]	44.29 [0.16]
Hansen-Doornik test	6.44 [0.38]	4.00 [0.41]

Notes: 1. t-statistics in parentheses.
2. p-values in square brackets.
3. The short-run estimates in the ΔS_t-equation are not reported.

TABLE 4. HYPOTHESIS TESTS

Null hypothesis		H_0	LR-statistic Full Model	LR-statistic Conditional Model
Stationarity of:	A_t	$\beta_{P_r} = \beta_S = 0$	42.37 [0.00]	8.60 [0.00]
	P_{rt}	$\beta_A = \beta_S = 0$	16.29 [0.00]	-
	S_t	$\beta_A = \beta_{P_r} = 0$	45.71 [0.00]	5.16 [0.02]
Individual exclusion of:	A_t	$\beta_A = 0$	8.82 [0.00]	8.60 [0.00]
	P_{rt}	$\beta_{P_r} = 0$	41.78 [0.00]	40.84 [0.00]
	S_t	$\beta_S = 0$	5.04 [0.03]	5.16 [0.02]
Weak exogeneity of:	A_t	$\alpha_A = 0$	67.48 [0.00]	73.26 [0.00]
	P_{rt}	$\alpha_{P_r} = 0$	0.97 [0.32]	-
	S_t	$\alpha_S = 0$	7.31 [0.01]	6.34 [0.01]

Note: p-values in square brackets.

The coefficient on the error correction term, α_A, is the speed of acreage adjustment towards long-run equilibrium and is -0.03. It has the *a priori* expected sign and is significant and indicates that the previous year's acreage disequilibrium is corrected by 3% each year. Adjustment is slow as expected, and it takes 10 years to achieve only 25% of adjustment towards long-run equilibrium. Similarly, α_S is the speed of adjustment of the replanting subsidy from disequilibrium and is -0.04. Again, it has the *a priori* expected sign and is significant. Adjustment of the replanting subsidy towards long-run equilibrium is also slow: disequilibrium is only corrected by 4% each year, and it takes 10 years for 33% of long-run adjustment to take place. Since both α_A and α_S are significant, there is bi-directional Granger-causality between acreage and the subsidy. Our focus is on acreage response and we find that rubber acreage is determined by the replanting subsidy, but the subsidy is also determined by acreage and own price. Normalising the cointegration vector on S_t shows that the long-run elasticity of the subsidy with respect to acreage is 0.86; and the long-run elasticity of the subsidy with respect to own price is -1.92 while the corresponding short-run elasticity is -0.224; and these estimated parameters are significant.

The Nerlovian partial adjustment model is nested in the VECM in (3) (Hendry *et al*., 1984; Hallam, and Zanoli, 1993). If the difference terms in (3) are significant, the more general VECM is preferred. In Table 3, the ΔP_r-coefficient is significant, the conditional VECM is preferred, and Nerlovian partial adjustment is inappropriate for describing the data.

SUMMARY AND CONCLUSIONS

This paper applies modern cointegration methods to estimate short- and long-run rubber acreage responses for Thailand for 1962-2009. Results show that a unique relationship exists between the planted acreage, own price and the replanting subsidy, and that the rubber price is weakly exogenous. Accordingly, a VECM is estimated by conditioning on the weakly exogenous price. The long-run own price elasticity of acreage is 2.24 while the corresponding short-run elasticity is 0.04. The speed of adjustment towards long-run equilibrium is slow, and only 3% of adjustment is completed each year, and this reinforces the low short-run elasticity. In the short run, farmers can adjust area in response to a price change only by a small amount and the reasons include substantial adjustment costs of investment, and inflexible labor and capital. In the long run, farmers are less constrained and can adjust planting more easily: they have more opportunities to adapt land for rubber production, to find labor for weeding, fertiliser application and tapping, and to accumulate investment funds.

Most previous studies of rubber acreage response in Thailand report low short-run own-price elasticities and this study supports that evidence. Our estimated short-run acreage response elasticity is close to those of Suwanakul and Wailes (1987), Yibngamcharoensuk (1988) and Aroonsiriporn (1989) but is lower than that for new plantings in Stifel (1973) which is around 0.8, perhaps because Stifel's sample covers the early stages of the development of rubber production in Thailand when land use was in the intensive range of production.[7] Our long-run planted acreage response elasticity is considerably greater than Suwanakul and Wailes' (1987) tappable acreage response elasticity of 0.31 which is estimated within an atemporal framework. Further, our long-run own-price elasticity is generally larger than those elasticities elsewhere where output (supply) is the product of acreage and yield. The atemporal frameworks of Behrman (1971) and Burger and Smit (1997), and the Nerlovian models of Jumpasut (1981) and Suwanakul and Wailes (1987) report inelastic supply responses; and Dowling (1979) using Almon lags, and Man and Blandford (1980) using Nerlovian adjustment report elastic responses ranging between 1.5-2.6. The simpler dynamics contained in models in previous studies do not to describe the data adequately.

Prima facie, it is perhaps surprising that the domestic rubber price is weakly exogenous in our model. Thailand is the world's largest producer of natural rubber with around a third of total output and it contributes over 40% to world exports. Over our sample period, the correlation between Thailand's domestic price and the world price from the Singapore Commodity Exchange is 0.97 with the Thai price being lower on average by $260/tonne because of margins for domestic dealers and exporters, the cess tax, transport costs, and the margin for traders on foreign markets. However synthetic rubber is a close substitute for natural rubber on world markets, and in 2009 natural rubber production comprised 44% of total production (IRSG). Thailand's influence on the natural rubber price appears weak and it could be considered as a price-taker on the world market.

Our estimate of the long-run elasticity of planted acreage in response to a change in the replanting subsidy is 1.17, and the government can stimulate the expansion of acreage by increasing the replanting subsidy. This subsidy is important to farmers because they face a temporary shortfall of income during the unproductive period before newly planted rootstock matures, and the subsidy mitigates against these losses. Participation in the replanting program also allows farmers to access various training schemes and information about production and marketing. We conclude that the replanting subsidy is a key driver for increasing rubber production in Thailand. However, a concern is that the replanting program fund is mainly obtained from the cess tax levied on rubber exporters; all rubber farmers pay the tax indirectly but the replanting program benefits only those who join the replanting scheme.

Our results also show bi-directional causality between planted acreage and the replanting subsidy, and an increase of 1% in the acreage leads to a 0.86% increase in subsidy. The policy of the Office of Rubber Replanting Aid Fund of increasing the subsidy as acreage increases appears justified because the most productive land is cultivated first and more extensive land which requires a higher subsidy is cultivated later. We find that the long- (short-) run elasticity of the replanting subsidy with respect to own price is -1.92 (-0.22), and the subsidy appears to be adjusted downwards as the rubber price increases.

The contribution of this paper to the literature is twofold. First and in contrast to previous studies of rubber supply response in Thailand, we adopt modern cointegration analysis to address the problems of restricted lag structures and spurious regression which are inherent in Nerlovian models estimated by classical regression methods. Accordingly, we can be more confident about the precision of the estimates. Second, we include variables omitted in previous studies, and we highlight the importance of the replanting subsidy.

There are two caveats to these results. First, data on new plantings, removals, land prices, and technical change from high-yielding varieties for example are unavailable and we adopt a simple model of planted acreage response. Second, we are unable to find long-run relationships that include competing crop prices, or input prices. There are two possible reasons for this finding: the first is poor data quality, particularly for the fertiliser price and the wage rate; and the second is that conventional cointegration tests, even with a Bartlett correction, may have poor size and power properties when the sample is of moderate length (Juselius, 2006, pp.140-141).

There are two lines of further research that could be pursued. First, panel cointegration methods with a richer, regional dataset would allow for heterogeneity between regions, provide more variability and hence less collinearity between variables, and since there are more degrees of freedom, parameter estimates are more efficient (Baltagi, 2001, pp.5-7). Second, some studies of rubber supply response in Thailand estimate output response rather than acreage response and our methodology could be extended to estimate total production.

In summary, we provide strong evidence that Thai rubber farmers respond rationally to economic incentives. Results show that estimated elasticities of rubber acreage with respect to own price are significant and positive, and pricing policies are effective for achieving/influencing desired acreage. However, the low short-run and high long-run price elasticities of acreage response suggest that rubber farmers adjust area by a small amount in the short run in response to a price change, whereas they make substantial adjustments in the long run. Any pricing policy requires a long lead time for it to become effective. Expanding the subsidy program to new areas would accelerate the response. The subsidy is particularly important to poor farmers who often have no access to credit from financial institutions.

ENDNOTES

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[1] This aggregates exports of liquid rubber latex and dry natural rubber which includes rubber sheets, block rubber, and crepe. Thailand is the world's largest exporter of latex with 1.00m tonnes (88% of world exports), and is the second largest exporter of dry natural rubber with 1.73m tonnes (32%) after Indonesia with 1.78m tonnes (37%) (FAO).
[2] The Thai government banned forest logging in 1989 because of environmental degradation caused by floods. Subsequently, timber must be logged from rubber plantations (Rantala, 2006, p.9).
[3] Personal communication with Office of Agricultural Economics, Bangkok.
[4] In samples of moderate length, trace tests are likely to have size problems and the Johansen approach over-rejects when the null is true. Accordingly, we use a Bartlett correction (Johansen, 2002).
[5] Model 1 accounts for neither intercepts nor deterministic trends in the cointegrating space and is unrealistic; and Model 5 is only appropriate if the data exhibit quadratic trends in level form which is difficult to justify when the variables are in logarithmic form since it implies an unlikely ever increasing or decreasing growth rate.
[6] Data sources: acreage planted (ha.) and price (baht/tonne) - OAE; and the replanting subsidy (baht/ha.) - personal communication with Office of the Rubber Replanting Aid Fund, Bangkok.
[7] With increased plantings, less productive land is used in the extensive range of production.

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